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THE ORGANIZATION OF RESEARCH¹

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I. THE CONCEPTION OF RESEARCH

RESEARCH has been for years past a term with which to conjure, but one to which often only the vaguest and most indefinite meaning has attached. It is frequently used as though it were a sort of trade name, a label wherewith to mark goods of a certain merchantable character. In point of fact there are at least as many types of research as there are research men—indeed probably more. Research may be good, bad, or indifferent; it may be thorough or careless, fundamental or accessory, substantial or superficial, and while certain of these distinctions are too obvious to be labored, there are others which deserve a word of comment.

A distinction often drawn, and having a certain practical validity, is that between research in pure science and research in applied science. It is easy to magnify this distinction quite out of proportion to the actual facts. The objects of research in pure science and the motives inspiring the work may be appreciably different from those encountered in the field of applied science. But the technique of the procedure in the two cases may be all but indistinguishable and either variety of research, if it is to survive the test of scientific criticism, must be based upon absolutely fundamental scientific principles. In the last analysis, the difference reduces almost wholly to the psychological question of motivation. The man working in the field of applied science has before him a concrete specific issue involving some immediate practical exigency. The worker in pure science has quite as definite a specific problem, but it is not one which has arisen out of, nor which necessarily exists in obvious relation to, an immediate demand. Beyond this I doubt if significant differences exist.

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Another distinction which is of great consequence for the development of research consists in the origination of new methods, as distinguished from the application of old methods in a new field. From the point of view of the value of the results obtained the difference is not always of marked importance, for it not infrequently happens that discoveries of crucial significance come out of the application of an accepted technique. But it is perfectly clear that we can make use of a distinctly less fertile and ingenious type of mind to carry forward the application of a method in fields slightly different from those in which it has been previously used than is required for the discovery of new basic principles and the invention of fundamentally new methods. For example, the discovery of the Roentgen rays is an achievement of a very different order from the devising of some new medical use of them, and yet the latter may be popularly adjudged the matter of prime human significance. Every university man is familiar with the phenomenon of a series of doctor's theses, each carrying out in a slightly different range—let us say in a series of biological species—methods devised perhaps by a professor in charge and by him tried out in a few groups to start with. Such work is accepted as original research and unquestionably has a measure of originality, inasmuch as there are almost invariably some new and unexpected conditions to be met which require modifications of greater or less degree in the application of the method. But original research in the largest and most generous sense of the term such work is not.

I venture to draw attention to the issue because research is commonly identified with marked originality, as though the two things were intrinsically synonymous. In the case of the most important research no doubt this is substantially true, but such research shades off through indistinguishable gradations to a form in which the element of originality is reduced to the vanishing-point. It would be a fundamentally wrong inference to assume that because the originality is small therefore the results which may be gained are of little value and that research of this character is to be discountenanced. The fact is that research work is capable of being organized in ways not wholly dissimilar to the organization of our great industries and as such is capable of appropriating and controlling intellectual capacities of the most varied kind.

I would accordingly urge that in our conception of research we look beyond the peculiar combination of intellectual traits, which may characterize any one individual, and think of it as

the organized technique of science itself for its own propagation. It is, so to speak, the reproductive process of science. When thus conceived it takes on a far larger and more momentous aspect than when thought of, as too often at present, as being a mere appendix to the process of science, a sort of luxury of the scientific idle rich. Such a conception is false in practically every essential particular, and yet it is not infrequently encountered in academic circles, especially where the traditional humanistic interests are exclusively cultivated.

II. DISTRIBUTION OF RESEARCH FUNCTIONS

At no point in the present administration of research interests in educational institutions is there perhaps more need for searching analysis of present practises than in the methods, or lack of methods, whereby particular lines of research are undertaken. Almost every great university is put in the position of attempting to foster all the major fields of research and an unlimited number of accessory ones. Local pride has repeatedly led to the effort to develop forms of research which may be intrinsically of minor consequence and altogether anomalous in the regions where they are undertaken. State institutions are constantly subjected to pressure of this character, leading to the formation of new departments, some of which have no substantial justification beyond the gratification of the ambition of some energetic professor or some small group whose interests will theoretically be promoted in this way. There exists at present no adequate device by which an indefinite continuation of these conditions may be avoided. Indeed, it is but quite recently that there has grown up any considerable body of opinion recognizing the wastefulness of the present practises. It is of course a matter of the utmost delicacy, and one calling for great breadth of knowledge and great sanity of judgment, to attempt in any fashion to allocate responsibility for particular kinds of research. At the very outset one is met with the contention that any such artificial distribution of functions would operate seriously to cripple individual initiative. And yet the contrary consideration is quite as urgent. To equip every university in the country to carry on research in agriculture, in forestry, in all the branches of engineering, and, for that matter, in all the physical, chemical, and biological sciences, would obviously be wasteful of equipment and physical resources, and all but impossible of execution in the matter of personnel. Certain rough lines of

division are in point of fact at present operative. Some institutions by mere virtue of the fact that they secured an early occupancy of a field have developed to a considerable degree of advancement research work in special directions which might perhaps have been more advantageously developed elsewhere. But meantime, being in possession of the property, it would be ill-advised to attempt to dispossess them. In any event while it is futile, and were it not futile it would be unwise, to attempt any arbitrary and coercive methods in the solution of this general problem, it is not too much to hope that by intelligent voluntary cooperation something may be done to safeguard the situation against an indefinite continuation of the present condition. Through the generosity of the General Education Board, the Education Division of the National Research Council is undertaking a careful study of the actual research facilities of the educational institutions in the country. Some illumination will certainly come from this analysis.

III. PERSONNEL

One of the first prerequisites for a satisfactory adjustment of the present complications is to be found in improved methods for the stimulation and selection of research men. There is a considerable public opinion suspicious of the utility of a great deal of the research which has been fostered by the government and by educational institutions. It is a conservative assertion to say that this opinion has a substantial basis in fact and that an appreciable part of the output of scientific research in any given year is of very trifling value from the point of view of either its immediate or its remote implications. But, as in most human processes, in order to make sure of the essential nucleus of valuable research material, we must probably encourage a considerably larger amount of productive effort than we can expect to realize upon at all completely. One hundred per cent. efficiency in such matters is not to be expected. Nevertheless, there is every reason to believe that we can materially improve the present methods of selection for research careers, and this in two directions: first, by discouraging the unfit, the second, by giving far more encouragement to those possessing the necessary native endowment.

In educational institutions, from which come by far the larger number of research men, it should be possible to establish filtration methods which will eliminate candidates for research careers who give too little promise of success. At the

present time the opportunity to carry on research is almost wholly dependent upon the moral and social initiative of the individual rather than upon his sheer intellectual endowment. If he be sufficiently persistent, he may secure opportunity to be free from portions of his other academic duties in order to prosecute research. And let no one underestimate tenacity of purpose in a research career, but it is not the only desideratum. I have no panacea to offer for the control of research privileges, but I should suggest that a more careful scrutiny, either by research committees or by directors of research, would assure a more promising allotment of opportunity and leisure than now exists. No doubt a practical distinction must be made at this point between the graduate student and the instructor. Both should be called on to justify their opportunities for large freedom in research, but the methods for handling the two cases would differ materially. I recognize at this point the danger of arbitrary discrimination, but I doubt whether it is of serious moment. Far more important, in any case, is the encouragement of the unequivocally gifted research man. This encouragement should be in part in the form of public recognition, both inside and outside the academic circle, and in part should take the form of increased opportunity for productive work. The National Research Council is at present, through the generosity of the Rockefeller Foundation, making an interesting experiment of this kind in the field of physics and chemistry by offering to a group of men, who have already demonstrated their capacity, an opportunity to give their entire time and attention through several consecutive years to uninterrupted research. It is confidently believed that this device will gradually produce a group of research men of the highest quality whose worth will in this apprentice period have been indubitably establish. If the experiment succeeds—and a similar procedure which has been in operation in England for a number of years gives every reason for optimistic prediction—there is no reason why the same principle should not be applied in other ranges of science. The research man deserves a living wage, public recognition of the unique contribution which he makes to social progress, and the best of opportunities for capitalizing his talents for scientific discovery.

In certain universities, if one may trust current report, there is crying need for the creation of a "research atmosphere," with all that it involves of appreciation for the peculiar requirements of the investigator. To plead for this argues

no callous disregard of the obligation to give instruction, but it does betoken the fundamental faith in research as the fountain head of creative intelligence, without which all education must become sterile. The solution of the problem will vary from institution to institution. In some, research committees, if energetic and patient, can produce admirable results. In others, different devices may be preferable. But the research man must ask if he expects to receive.

IV. TRAINING RESEARCH MEN

Never before has the outlook been so grave for the procurement and training of the required number of research men. Stimulated in large measure by the experiences of the war, the great industries, to say nothing of commercial concerns of all kinds, are calling for expert scientific men often to carry on explicitly research forms of work, in numbers quite exceeding the present available supply. They have been raiding college faculties in a fashion only too well understood by this group present here to-day. Each one of us can count a score or more of men among our colleagues who have been tempted away from the high thinking and distressingly plain living of the academic life to accept a competency, and often much more, at the hands of the industries. The tragic part of this transaction is not that the fine gold of academic self-denial is thus transformed into a baser social metal—regarding this aspect of the case most of us, if not envious, would at least be complacently indifferent—but that by the removal of such men from the universities these institutions, in which at present alone are to be found proper conditions for the training of scientific research men, are seriously crippled, with little or no possibility of making good with any promptness the damage thus done.

One can perhaps hardly blame the leaders of the industries for taking good men wherever they can find them, and in view of the low estimate in which college and university men have generally been held by the great lords of business and industry there is some poetic justice in seeing them obliged to provide themselves at a critical stage of their development with a personnel largely selected from among these previously despised members of the community. But the suicidal character of this policy, if carried forward without modification, is too obvious to require comment. It is surely a short-sighted policy, against which the experiences of the war give every necessary warning, to use up at one fell swoop all, or any large part of, the national resources for producing a trained personnel. Yet this is exactly what is now going on.

Stripped of its equivocations and apologetics, what the case amounts to is that the universities must by one means or another be enabled to pay such salaries to their scientific men and give them such conditions of work as will constitute an adequate offset to the temptations offered by business and industrial life. It is known that we desire to encourage the introduction of the highest type of scientific talent wherever it can be used in commerce and the industries, but as a national program it is our solemn duty to draw public attention to the ultimate price we shall pay if we continue the present process. This price will unquestionably be no less than national scientific bankruptcy with the inevitable reflex of this in an ineffective scientific equipment of the industries themselves. Nations which guide their affairs more sanely in this particular will certainly outstrip us. If the industries are going to rehabilitate themselves in any large degree through improved scientific methods—and this seems to be what the immediate future has in store—they must be brought to appreciate that either through governmental intervention, or through their own direct contributions, the universities must be kept at a high level of efficiency in the training which they give to young scientists.

In my judgment this particular association can hardly do any one thing more useful for the safeguarding and developing of research interests than by setting its face energetically to nation-wide propaganda for the speedy betterment of the conditions of research workers and the trainers of research workers in universities.

In the minds of most college and university authorities there seems to be little or no question that the ordinary work of instruction should go forward side by side with training in research and with the actual research work of the scholar in charge. To this view, however, there are not a few vigorous dissenters. They urge that the conjoining of teaching and research in American institutions is more or less of a national accident and that there is no necessary connection between the two. They insist, and with much force, that to expect a man to do good research who is obliged to teach several hours a day, or even every other day, is in many kinds of research work to expect the impossible. A man needs not only the uninterrupted concentration of attention, but in the case of many types of investigation he must literally be personally present, watching and controlling the course of the phenomena which he is studying. It seems more than open to question whether or not universities have as yet experimented with sufficient

boldness and ingenuity in devices to assure research workers time uninterrupted by the routine of instruction. A few so-called research professorships have indeed been established, but these are the exception, and their success is not as yet wholly assured. Is it, however, impracticable to insure to competent research men for some definite amount of time—say, six months in the year, or some other convenient period—complete freedom for research work? In institutions whose schedule permits, some men have been able to free themselves from class-room work for half the week and in this time to achieve a large amount of research. Of course the practical difficulty which the administrative officers are confronted with is the securing of the necessary amount of instruction to care for the unlimited number of students who insist upon besieging our universities. There is in many of these institutions entire willingness to give the research man reasonable opportunities, but there is often the insuperable barrier just referred to.

As is well known, there is also an appreciable body of opinion holding that research work should be organized under the jurisdiction of exclusively research institutes and that it should not be attempted on any large scale in universities. Whatever may be said of the ultimate merits of this position, it represents at the moment a purely academic expression. There are not institutes enough, and there will not be in any near future, to care for even a fraction of the research work which must be done. Moreover, whether the opinion is justified by final experience or not, it is at present unquestionably the view held by the vast majority of academic and scientific men that both instruction and research are in the last analysis benefited by their juxtaposition in one institution. Furthermore, it must not be forgotten that the purely research institution is sterile in the production of trained personnel. It may train a man in its own technique within the field of its own endeavor, but it must receive the recruit from the university already trained in the fundamentals of science, and from no other source can this supply at present be secured. Whether men trained in institutions that themselves do not conduct the highest forms of research are generally likely to become successful investigators in the institutes is a question to which only the most daring would venture an affirmative reply.

V. ORGANIZATION AND COOPERATION IN RESEARCH

It is a not infrequent remark, and one which I believe to be measurably just, that science despite its magnification of

method has never seriously worked out the method of its own organization. For the most part, it has thus far rested on individual initiative and on such loose forms of cooperation as are based upon the magnetic or coercive personality of some one scientific man. Assuredly, no one expects to create a system of scientific progress which will in any sense be independent of the presence of commanding intellects; but it is equally certain that scientific men have as yet achieved only the most elementary beginnings of the organization of scientific interests. Indeed, it has been something of a fetish among scientists that we must rely upon individual inspiration and initiative, and that the individual worker must be safeguarded in every possible way from the corroding influence of administrative organization. It has unfortunately been generally assumed that an organization which interests itself in research will inevitably exercise such a depressive influence on the research worker. This I believe to be essentially untrue in theory, and I am at the moment connected with an organization which is directing all its energies to proving it untrue in fact. No doubt there will always be wide ranges of scientific work where the individual must toil more or less alone, but, on the other hand, no one who has thoughtfully contemplated the conditions under which modern science does its work can have failed to be impressed with the innumerable unimproved opportunities for co-operation.

In the first place, we have, through processes which I need not stop to describe, parceled out the field of knowledge to a great group of sciences, each of which, perhaps not unnaturally, is disposed to claim supreme jurisdiction over its own bit of territory. The world of science has thus come to present somewhat the appearance of an English landscape with its checker-board effect of small fields set off from one another by high, impenetrable hedges. To one who toils inside such a field, the universe is limited by his own hedgerow, and inside it he desires to be left in peace to cultivate his crop as best may suit him. The parable has of course its element of exaggeration, but it is unfortunately not so much exaggerated as one might wish, and there are not a few scientists whose thought and speech would seem to indicate an amazing lack of appreciation of the intellectual context of their own work.

The actual fact, of course, is that the dividing lines of science are, like the hedgerows, in large measure arbitrary and practical, and consequently subject to persistent modification. Practically speaking, chemistry and physics are profitably con-

ducted as separate sciences, and yet they overlap and impinge upon one another in ways which have already created the border science of physical chemistry. Botany and zoology have similar relationships. Chemistry and physiology are neighbors of the most intimate kind. Psychology and neurology can hardly get along the one without the other, and so it goes. Under the present organization of science—or lack of it—there is no localized responsibility for bringing together in cooperative enterprises research workers occupying fields that are thus convergent or overlapping. There is genuine need for such cooperative work in many different directions, and one of the first obligations of any method adopted to further the general interests of scientific research must be the providing for investigations which shall thus bring together the scientists now occupying neighboring but distinct fields.

Obviously organization in research must involve something substantially different from organization in enterprises of other kinds, for example, war, industry, sport, and exploration. Organization, I take it, looks primarily to the efficient mustering of all the resources available for a given undertaking, and as the ends desired vary, so do the means for their attainment. In war the individuality of the private soldier must be in large measure subordinated to the conceptions of the high command, and while any ideas he may have to offer may theoretically be received, in practise his initiative is reduced close to the zero point through the larger part of his service. Obedience, rather than initiative, is the first military virtue. Similarly in industry, ideas are desired and generally encouraged, but nevertheless in the stress of the day's work each individual workman must play his previously assigned part, play it promptly and without debate, become in short a cog in the great machine; otherwise production is blocked and economic disaster may be the result. Initiative and ingenuity are essential at the top of the organization. Moreover, ideas supplied from workers at any level of the process are welcome in progressive industries, but the actual application of them to the procedure in hand must ordinarily come from above and the individual unit in the machine must function more or less mechanically.

Evidently organization in research calls for quite a different distribution of effort. Individual initiative, resourcefulness, ingenuity, imagination, vision, must be kept at a high pitch all along the line. Here we are not concerned with quantity production of a stereotyped product, of which the hundred thousandth specimen shall exactly resemble the first. On the

contrary, the product is in some sense constantly varied, and unless it prove to be varied, the process has failed of its purpose, has degenerated into mere hack work, or has been based on essentially mistaken principles. On the other hand, the conception not infrequently entertained that the research man is necessarily the genius working in seclusion is essentially untrue to most of the facts. Many a genius works in seclusion and all research men must be free to work undisturbed at the task in hand; but there are many forms of scientific problems, whose solution is essential to the modern world, which are so complex that no one scientist is equipped to deal with them single-handed. Either they must wait for their solution upon the accidental arousal of interest in the appropriate group or there must be some definite purposeful cooperation established. The great fundamental discoveries may perhaps, as a rule, await the wholly spontaneous efforts of the great genius, but many discoveries of the utmost value to humanity have come from the somewhat accidental observations of men of essentially moderate talents. And not only so, but a very large fraction of the progress in our scientific knowledge in the last fifty years has come, not from the work of the occasional genius, but from the hard, persistent, thoughtful investigations of men who would never be classed as geniuses in any ordinary sense, but rather as trained men of large native ability. This group of men is more often than not eager for those forms of contact with other scientific workers which shall enlarge their own outlook upon the problems with which they are engaged and which shall enable them to pursue more effectively their individual researches. For such men betterment of the machinery of scientific cooperation and the dissemination of useful scientific information not only involves no invasion of their individual initiative, but often is the condition of its successful expression.

To put it in slightly different form and at the risk of repetition, one may say that a fairly prevalent conception of research associates it with the somewhat mystical intellectual operations of the genius, or "near-genius," to tamper with which is a kind of profanation. In this view one must simply wait upon the deliverances of fate. To attempt to assist by any devices of organization is futile. As a matter of fact, large areas of the most needed research lie in territory where properly trained men of talent, given proper conditions of work, may produce constantly and in increasing measure results of the utmost consequence. But one of the conditions of maximal efficiency is that they shall work inside the framework of a gen-

eral program in which there is intelligent cooperation in the allocation of the field and in the constant communication of results achieved. Such distribution of responsibility and effort is entirely consonant with the fullest actual initiative which any scientist can desire. No one compels him to investigate where he does not desire so to do, but by a centralized device for planning he can make his effort count for far more than when he works wholly alone. This is as true of the zones of pure science as it is of the regions of applied science where organization is often thought of as less foreign to the ends sought. Indeed in the research laboratories of a few of the great industries such cooperation has produced the most remarkable results.

Even if organization in research meant no more than thoughtful discussion and planning among a group of men engaged in the same lines of work, it would be immensely worth while. For example, here are a dozen forestry experts in position to determine the research problems which shall be first attacked by the staffs of a dozen different organizations. If there be no contact among them, they may all decide to start upon exactly the same problem or upon utterly disconnected problems. Undoubtedly, some excellent result may emerge under such conditions. Yet nothing is more certain than that the energies of the entire company could have been invested to far better purpose with much less of wasted effort had there been intelligent planning before work began. There is abundant practical experience to justify this conclusion. Repeatedly it has occurred that men working in entire ignorance of what others in their field were doing have traversed the same ground and with results which in no wise justified the wasted effort.

But, as a matter of fact, organization in research means much more than this. Many highly important projects, as we have observed before, involve for their execution the converging efforts of men in different fields of science and in applied science in particular. The agencies interested in improvement of methods must at times come together to set in motion the necessary research work, or it will not get done. Furthermore, the technique for the prompt and convenient dissemination of information regarding discoveries in research is at present lamentably imperfect, and we shall never capitalize our scientific energies at anything like their full value until this condition is removed.

As a matter of fact, cooperation in research may be profit-

ably developed, first, as between scientists working upon related problems in the same general field, say, physics; second, as between scientists in different but adjacent fields, *e. g.*, chemistry and biology; third, as between scientists in different countries, where such cooperation is often essential to success; fourth, as between agencies like the industries requiring the benefits of research; fifth, as between organizations, *e. g.*, government bureaus, experiment stations, and universities; and sixth, by improvements in methods of rendering easily accessible information regarding scientific discoveries.

As practical illustrations of the type of thing we have in mind certain of the problems of public health may be mentioned; for example, sewage disposal presents a question in which the organic chemist, the colloid chemist, and the sanitary engineer are all necessarily involved. The National Research Council has secured the services of a very representative committee to study the fundamental problems of food and nutrition, a problem which in this same way represents the combined interests of a considerable group of sciences. The successful solution of the problem can not be reached without the cooperation of men representing these distinct but related fields of science. One of the most promising ranges of contemporary research is in that border-line group of problems in which the biologist, the chemist, and the medical scientist find their interests converging. A physiological chemist, however learned he may be, is compelled to turn from time to time for scientific assistance to one or another specialist in this group of neighboring sciences. Indeed, it is practically impossible to pitch upon any problem in modern life whose complete solution does not involve an appeal to several lines of scientific approach. In certain cases, through more or less happy accident, the required scientific cooperation is easily secured, but in many instances there has been no adequate provision for securing such combined attack.

Again, within the field of any one of the great sciences, there is opportunity for a kind of cooperation in research which has never been undertaken on any large scale and which can, if properly stimulated and guided, produce results of the highest consequence. For example, there is at the present moment being considered by the National Research Council a nationwide investigation of the problem of reforestation such as no extant single agency can hopefully attack. Similarly, it is planned to study the problems of soil fertilizers in different regions of the country by means of cooperative effort in a considerable group of appropriate agencies.

In certain ranges of science there is not only necessity for the cooperation of individual scientists working on different aspects of the same central problem, but there is also need for international cooperation. One only needs to cite such problems as those of astronomy, seismology, meteorology, and terrestrial magnetism to appreciate how essential simultaneous observations at various points of the earth's surface may be. In such cases international cooperation is absolutely indispensable. Nor are the forms of profitable international scientific cooperation in research confined to the spheres of astronomy and the major phenomena of the behavior of the earth's surface. The study of the behavior of plants and animals under certain standard conditions will afford numerous instances in point.

Perhaps the most obvious illustrations of the possibilities of successful cooperative investigation are represented in certain forms of industrial research, where a group of producers come together and establish a research organization, either establishing laboratories of their own for this purpose or utilizing extant laboratories through which they can arrange for the admittance of their investigators. It is of course well understood that certain of the great manufacturing industries, particularly those connected with the development of electricity, have developed laboratories of the most elaborate kind and of a very high degree of efficiency. But the smaller concern can not afford to develop its own scientific staff, and consequently the cooperative device is found to be the best substitute. This process, which has been carried to a considerable development in Great Britain, is being rapidly fostered in this country, and gives promise of extremely valuable results. Several different methods of procedure are feasible, but time will not permit further discussion of the matter here.

Finally, one may mention the types of cooperation in research which may be achieved by the establishment of more intimate contact between the organizations and institutions now actually engaged in such work. As has been already indicated, we have at present, as the main features of our national research equipment, certain of the scientific bureaus of the federal government and the several states, certain large research foundations, including a few of the great museums, a group of research enterprises in the industries, and the research work done in our universities. In each of these, individuals are at work on problems which, so far as is known to the men engaged upon them, are at the moment not under attack elsewhere.

But our present organization is totally devoid of any adequate means for securing information as to the research work at a given time in progress. In consequence, it repeatedly happens that men are found to have been working on common problems, investing time and energy which might have been expended to far better effect could they have been brought in touch with one another and have learned each what the other had to give in the way of knowledge already ascertained. In the case of the industrial laboratory, both the economics and the ethics of the case render it improper that information should be disseminated as to what is being learned. Even scientific men working alone as individuals have oftentimes been extremely jealous of their prerogatives in the matter of priority of scientific discovery, and have treated their work somewhat in the spirit of the trade secret of the industries. But over against this relatively small group there has always been a larger and more open-minded body of scientists eager to learn whatever could be brought to bear upon their own researches and willing and ready to communicate to others whatever they had to offer of worth. Generally speaking, the ethics of scientific research outside the industrial laboratory is rapidly coming to a point which commends and demands publicity. Indeed, it may be said that this condition has already substantially arrived. Men are eager for more prompt and adequate means of publication of scientific work, and one of the crying defects in the scientific situation as a whole, one which is far more serious in some branches of science than in others, is the need, first, for a central clearing-house of information regarding current research work and its status from month to month and year to year; and second, far more complete and more effective modes of publication of scientific results. Publication needs to be more prompt and needs to be accompanied by much more adequate methods of abstracting and indexing than at present are in operation. To these problems, also, the National Research Council, through its Division of Research Information, is turning its hand, and we hope to be able not only to point the way to better conditions, but also to make a substantial beginning in the actual improvement of these conditions. I will not pause to discuss the entire program of this service, but I may simply say in passing that it contemplates catalogues of research laboratories and of current investigations, sources of information, laboratory facilities, catalogues of scientific and technical societies with indexes of foreign reports, and a somewhat detailed program for the improvement of scientific publications, with particular regard to systems of abstracting and indexing.

VI. ORGANIZATION OF NATIONAL RESEARCH COUNCIL

To assist in meeting some of the needs of scientific organization in the United States, the National Research Council has been organized. It attempts to achieve in a democracy, and by democratic methods, such a mobilization of the scientific resources of the country as shall permit their most effective use, not only in times of crisis such as war, but also continuously in time of peace. The German government had succeeded under autocratic methods in carrying such organization to a high degree of perfection and had procured the most striking results, not only in the military administration, but also throughout the entire field of industry. Whether we shall be equally successful under the voluntary extra-governmental plan which we are developing remains to be seen. It may, however, be said at the outset that, rightly or wrongly, the opinion of scientific men is substantially unanimous that in our country an enterprise of this character can reach its highest possibilities only when freed from the restraint of government control. This, however, should in no wise be understood as reflecting upon the efficiency of the scientific work carried on by the various departments of the government. It does, however, argue a widespread conviction based on experience that these departments, despite their many great advantages, must of necessity work under limitations of a very definite and often unfortunate kind.

As the first step in securing a democratic foundation, the National Research Council is based upon the election of members by the great scientific societies of the nation, some forty being represented in the present roster with a constituent personnel running up into the thousands. These representatives from the scientific societies are organized in divisions, of which there are seven representing science and technology. Each such division elects a chairman, who becomes a salaried officer of the council, resident in Washington for one year, and in charge, together with an executive committee of his division, of the scientific work to which the division decides to set its hand. Provision is made for a certain number of members of each division to be selected at large, thereby insuring as far as possible the presence of a thoroughly representative scientific group, for it may at times happen that some important scientific interest is by accident omitted in the elections from the societies.

The council has also six so-called general divisions whose officials are appointed by the executive board of the council, and who conduct the work of the divisions much as in the case of the science and technology group. The personnel of these divisions is determined by the executive board, with the exception of a few persons who are ex officio members. These divisions cover foreign relations, the federal government, the states relations, education, industrial relations, and research information. The Government Division has representatives of each of the scientific bureaus of the government, and is intended to foster, so far as possible, cooperation among such bureaus and among the outside scientific agencies working on similar problems. The Foreign Relations Division has to do with foreign scientific societies. An International Research Council was established at Brussels during the past summer and will take the place of the old international associations and unions which, in forms somewhat modified by the war, will comprise the international unions organized under the International Research Council. The States Relations Division concerns itself with the attempt to foster helpful cooperative relations among the scientific bureaus and other scientific organizations of the several states. There appears to be opportunity here for an outside disinterested agency to render very great assistance. The Educational Division has to do with the interests of research in educational institutions in all its aspects. This division is beginning its work by a careful study of the actual facilities for research in our American educational institutions. It is hoped that by bringing together reliable information about these conditions it may be possible to formulate a more effective program for the utilization of such resources as we now enjoy, for the improvement of the same and for the development of a larger number of better-trained research men. Any rational adjustment of the program of research development in our universities, such as was referred to earlier in this paper, involves a careful preliminary scrutiny of the extant situation. There are some types of research work whose development can be justified only at a limited number of institutions. To have a great group of universities each attempting to do such work is wasteful of personnel and material resources alike. We shall hardly, however, be able to move on to a saner distribution of scientific effort until we know more precisely what are the actual facts in the case, much less can we educate public opinion to accept a reasonable distribution of responsibility.

The Research Extension Division has as its work the stimulation of research in the industries. It seeks particularly to bring into contact industrial groups interested in improving their scientific technique, with scientific men and agencies competent to render the necessary assistance.

The Research Information Service involves a program in many ways the most nearly unique which the council has to offer, in its attempt to create mechanisms for giving prompt and accurate information regarding, not only the finished products of research of all kinds and in all parts of the world, but also the conditions in current research. Its general intentions have already been briefly described and need not be repeated.

Taken in its entirety the work of the council is to be understood as primarily one of stimulation of research in both pure and applied science, and in the creation of an enlarged and better-trained research personnel, with particular emphasis upon the securing of cooperation wherever this can be profitably accomplished—cooperation as described above among scientists in the same field working on different aspects of a common problem; cooperation among scientists in different fields, whether at home or abroad, studying a group of related problems; cooperation among research organizations; and, finally, cooperation among agencies which require the services of research men and research organizations.

The council is itself frankly a piece of research, a great experiment, whose outcome we await with undisguised interest. Its purposes are worthy beyond question. If its methods be unsound, better ones must and will be devised. Meantime it invites your sympathetic support and offers you whatever service it can render.